Volume II February, 1925 *Number 2*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Steam Turbine Lubrication

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
TEXACO PETROLEUM PRODUCTS

TEXACO LUBRICANTS

For Steam Turbines

Make	Type	Drive	Mode of Lubrication: Bearings	Mode of Lubrication: Gears	Texaco Lubricants Recommended
Alberger Pump & Cond. Co.	Curtis	Direct	Ring Oiled		**Regal Oil B**
		Geared	Ring Oiled	Force Feed	**Regal Oil C**
Allis-Chalmers Mfg. Co.	Parsons	Direct	Force Feed		**Regal Oil A**
	Parsons (*Non-cond.*)	Direct	Force Feed		**Regal Oil C**
	Parsons	Geared	Force Feed	Force Feed	**Regal Oil C**
Bath Iron Wks., Ltd.	Parsons (*Marine*)	Direct	Force Feed		**Marine Turbine Oil M**
		Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Bethlehem Shipbldg. Corp.	Curtis (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Carling Turbine Blower Co.	Carling	Direct	Cup lubricated		**Star Greases**
Coppus Engineering Corp.	Curtis	Direct	Ring Oiled		**Regal Oil C**
		Direct	Grease lubricated		**Star Greases**
Wm. Cramp & Sons Ship & Eng. Bldg. Co.	Parsons (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Dean Hill Pump Co.	Wait	Direct	Ring Oiled		**Regal Oil B**
		Direct	Force Feed		**Regal Oil A**
		Geared	Force Feed	Force Feed	**Regal Oil C**
De Laval Steam Turbine Co.	De Laval	Direct	Ring Oiled		**Regal Oil B**
		Direct	Force Feed		**Regal Oil A**
	De Laval	Geared	Force Feed	Force Feed	**Regal Oil C**
	De Laval (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
W. & A. Fletcher Co.	Parsons (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Fore River Ship Building Co.	Curtis (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
General Electric Company	Curtis	Direct	Force Feed		**Regal Oil A**
		Geared	Force Feed	Force Feed	**Regal Oil C**
	Curtis (*Vertical*)	Direct	Force Feed		**Regal Oil A**
	Curtis (*Marine*)	Direct	Force Feed		**Marine Turbine Oil M**
	Curtis (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Hallidie Co.	Parsons (*Marine*)	Geared	Force Feed	Force Feed	**Marine Turbine Oil H**
Ingersoll-Rand Co.	Ingersoll-Rand	Direct	Force Feed		**Regal Oil B**

(*Continued on Inside Back Cover*)

Note: (a) On direct drive turbines, where bearings are lubricated by force feed, if temperature conditions are abnormal, substitute Regal Oil "B" for Regal Oil "A."

(b) On geared turbines, if temperature conditions are abnormal, substitute Regal Oil "E" for Regal Oil "C."

(c) On ring oiled bearings, where temperature conditions are abnormal, it may be necessary to substitute Vanguard Mineral Cylinder Oil for Regal Oils.

(d) For the lubrication of turbines not listed above, if conditions are such that the proper grade of Texaco Lubricants can not be determined upon by comparison, the matter should be taken up with the Industrial Engineering Department of The Texas Company.

LUBRICATION

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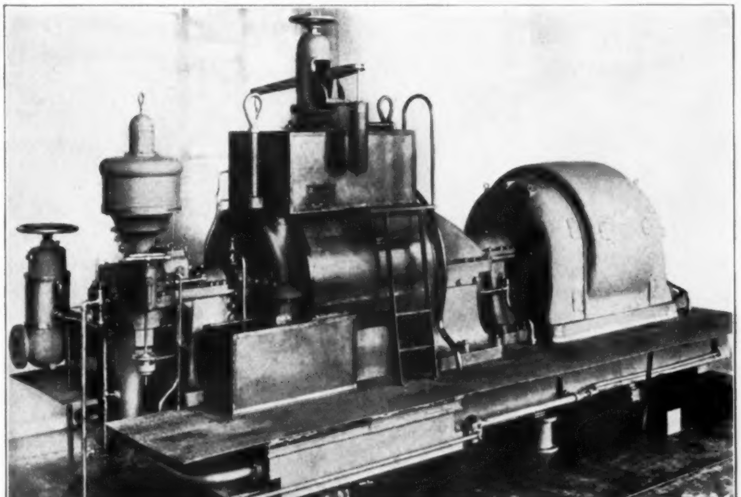


Courtesy of Westinghouse Elec. and Mfg. Co.

Fig. 1.—Side elevation of a modern steam turbine showing details of construction, the necessary oil and water piping and the governor details.

Steam Turbine Lubrication

ACHIEVEMENTS in the electrical industry in the United States, with a forecast of its probable growth over the ensuing several years are indicative of a marked increase in prime mover capacity. From an approximate total present power load of 40,971,000* K. W. as of January 1, 1925, it is predicted that by January 1, 1933, the connected load will have mounted to 83,580,000 K. W. In other words, an increase of 42,609,000 K. W. is a logical prediction.

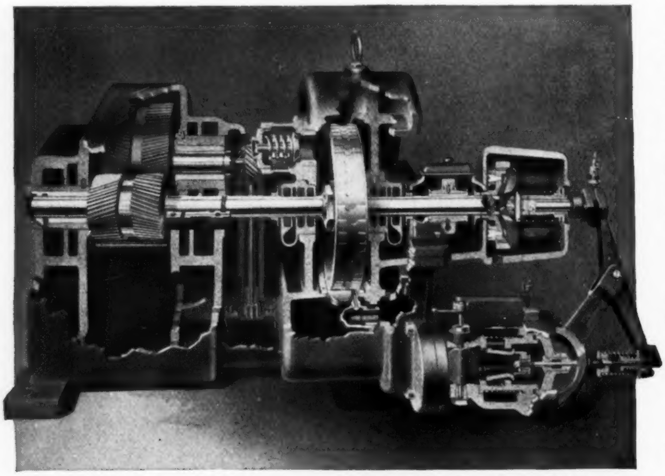
*"Electrical World"—Annual Progress and Statistical Number, January 5, 1924.

Of course such load increases will involve marked additions in steam turbine installations. In fact, turbine generating equipment is expected to amount to 60% of the total prime mover additions and extensions which will probably be necessary.

Naturally, with such a vast increase in the number of steam turbines a very logical probability, the question of adequately lubricating these to bring about a maximum of economy and efficiency is of prime importance to the oil industry. For example, based on an annual unit cost to lubricate of approximately

1/7 of a gallon per kilowatt output, the oil for steam turbines alone to-day involves approximately 70,000 barrels, at a probable cost of $1,750,000. To this should be added almost an equal amount of oil consumed in hydro-electric turbines and other types of prime movers such as steam and oil engines.

While this huge volume of oil is, of course, of much interest to the oil industry, quite as important is the fact that this oil must be one of the most highly refined of the petroleum products on the market. For the steam turbine is regarded as imposing more exacting requirements upon lubricating oils than any other type of industrial machinery.



Courtesy of The Terry Steam Turbine Co.

Fig. 2.—Cut-away view of a combined turbine and gear unit with the turbine and gear casing cast integral. This machine is frequently used as a stoker drive. Relation of gears, bearings and other essential parts is clearly shown. Note the three point (or bearing) support.

THE PROBLEMS INVOLVED

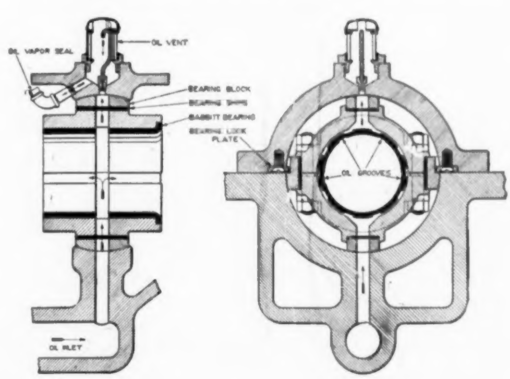
The essential problems which are involved in the lubrication of the steam turbine are (a), cessation or impairment of lubrication, and (b), variations in the rate of heat abstraction. The reason for this is the fact that the oil ways and oil piping will tend to become clogged or obstructed by sludge and emulsified matter. These latter are developed by the use of contaminated lubricants or products which have been improperly refined. In either case there is no logical excuse, for not only is it possible to get good turbine oils which have been carefully prepared to meet the existing known requirements, but also it is possible to sufficiently purify them while in service, in order to enable them to withstand the operating conditions which tend to impair them.

In order to solve these problems, naturally the first precaution as stated, must be to use an oil that will not emulsify readily with water. According to Funk,* laboratory data indicate that unless water is present a turbine oil subjected to heat or air does not develop emulsions even though it may become organically acid to a certain extent. Furthermore, Mr. Funk believes that oils which develop high acidity when moisture is absent will emulsify and sludge the worst when agitated in contact with moisture. There is as yet, however, no direct proof that increases in organic acidity alone, without formation of emulsions and sludges, is especially dangerous. Furthermore, attention is called to the fact that sludging is not necessarily dependent upon the presence of water, as oils will sludge from heat alone, but the presence of water may assist in its more rapid formation under certain conditions.

For a turbine oil to be as effective a solution of these problems as possible, it should therefore, be able to withstand:

1. The oxidizing and acid-forming effects of heat and air.
2. Emulsification with water.
3. Development of sludges from such emulsifications.
4. The catalyzing effects which dust, dirt and metallic particles (especially of copper and brass), involve in the formation of sludges.

From the viewpoint of the oil manufacturer, these are existing detriments which can only be satisfactorily met by the production of an oil which will show a minimum of breakdown



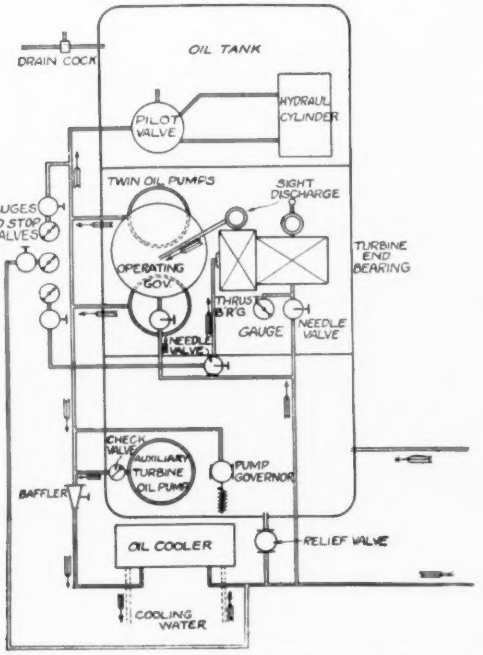
Courtesy of Allis-Chalmers Mfg. Co.

Fig. 3.—Details of a turbine bearing designed for force feed lubrication. Path followed by the oil is indicated by arrows.

*N. E. Funk. "Journal of Industrial and Chemical Engineering" Page 1083, October, 1924.

reaction. They will usually be prevalent possibilities in every turbine which his oil will be called upon to lubricate.

The turbine builder is, however, more intimately concerned, inasmuch as it is within his province to alter or improve the design of his equipment so as to render the occurrence of such of these phenomena as are dependent upon others, as difficult as possible.



Courtesy of General Electric Company

Fig. 4.—Diagram of the lubricating system for Curtis steam turbines of 30,000 K.W. and above.

For example, water is regarded by many authorities as the basic cause of emulsification. Therefore if a turbine and oiling system could be so designed as to eliminate the chances of water leakage or condensation occurring, provided the original oil was water-free, there would very probably be no emulsions formed.

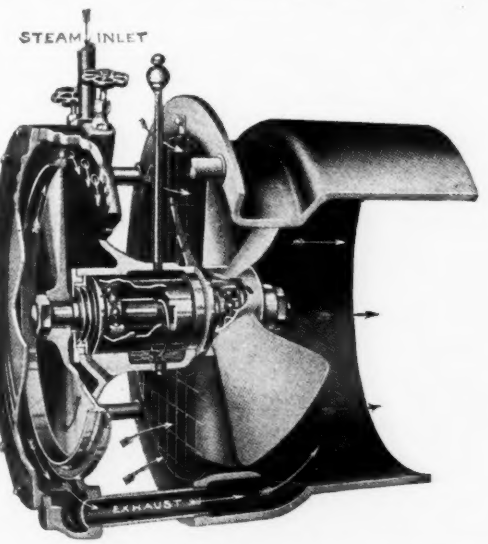
It is interesting to note that sludges are also dependent upon the catalyzing effects of certain metals or foreign matter, for their formation. Granting that the presence of a certain amount of water and other impurities is a certainty, emulsions and sludges will be formed in the average turbine. Effective oil purification should bring about the removal of these, however, before their proportion becomes dangerous. From the turbine builder's viewpoint, therefore, his machine and oiling system should be so designed as to permit of ready separation of impurities from the oil by means of the reconditioning apparatus.

General operating conditions are not conducive to satisfactory lubrication unless the turbine oil is capable of meeting requirements. In the first place, heat and air will always be present, since it is practically impossible to build a turbine oiling system so that the parts involved are absolutely air-tight. As a result air will get into the oil during its circulation through the system or in splashing over the gears. Dust and dirt are in turn always present in the air to a certain extent, wherever the oil is in passage. Therefore, it is logical to expect that foreign matter of this nature will find its way into the oil to not only cause abrasion and corrosion but also to act in the same catalytic manner as metallic particles.

Furthermore, the matter of acid and alkali must be taken into account. A turbine oil should always be neutral from this point of view. As previously discussed, organic acids may or may not be detrimental, depending on the type of acid. Alkalies in turn tend to bring about the formation of soaps in the event of their being agitated with oil and water. Not only may impurities of this nature tend to clog and obstruct the oiling system, but they also may be difficult to separate from the oil.

CONDITIONS THE OIL MUST MEET

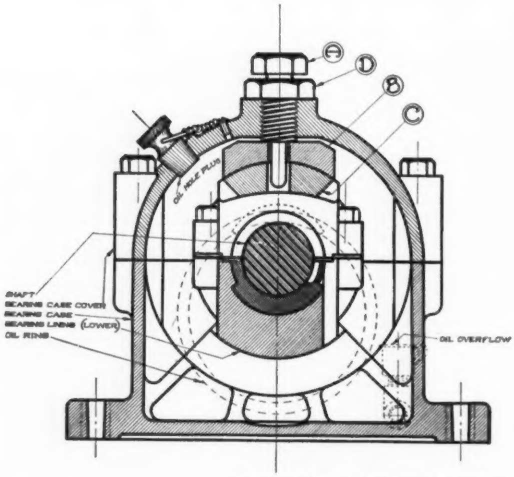
The above detriments are so intimately related and contingent one upon the other, that their action as destructive agents can only be clearly understood by a detailed individual discussion of the operating conditions which the oil must meet.



Courtesy of Coppus Engineering Corporation

Fig. 5.—Details of the bearing and lubricating system of a modern turbo-blower. Note that this is a ring-oiled ball bearing.

In fact, from the viewpoint of the operator who must lubricate a steam turbine as it stands, and who will normally have little to say in regard to any alteration or improvement in design for the purpose of reducing these



Courtesy of B. F. Sturtevant Company

Fig. 6.—Line sketch of a turbine ring-oiled bearing showing details of construction. (A) is the adjusting bolt which by tightening down, causes the spherical seat (B) to grip the linings (C); (D) is the lock nut which holds (A) in position. This arrangement does away with the necessity for using shims between the bearing casings.

detriments, the operating conditions which he must counteract by means of lubrication and purification of oils in service are all-important.

In general these will involve:

(a) The possibility of water contamination.

(b) The subjection of the oil to conducted or radiated heat.

(c) The occurrence of oxidation, and

(d) The ultimate formation of organic acids and sludges.

Water

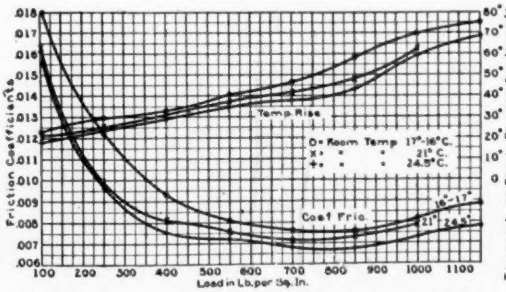
In practically every turbine installation water contamination of the oil will be a possibility. The entry of water may occur through steam leaks on account of the shaft packing glands or water seals not functioning properly; through leaks in the cooling coils of the oil cooler; or, as is more usually the case, from condensation of moisture in the air. Especially is this latter liable to occur when the turbine is shut down, at which time the inner metallic surfaces of the lubricating system will be relatively cold, serving more readily as a condensation medium.

Water is considered detrimental to a turbine oil in service in that it is an active agent in the formation of emulsion and, under some conditions, sludge. Where the oil is in a sufficient state of purity, separation from water will normally occur comparatively readily, for the emulsion caused by agitation will be of a relatively temporary character. A mixture of water and oil, however, when subjected to the customary rapid rate of circulation, in the presence of air, and the higher temperatures usually prevalent in turbine service, will subsequently develop permanent emulsions due to oxidation of the oil.

By some engineers oxidation is believed to be the basic cause of lubricating failures in the average turbine. According to Bromley,* oxidation is the cause of organic acidity and sludge. In other words, oxidation is the cause of an oil deteriorating or losing its durability. To date the petroleum industry has been unable to devise a means of preventing oxidation through suitable refinement of the oils. This is due in part to the relative impossibility of so fractionating their products as to absolutely preclude the presence of certain of those hydro-carbon constituents which lend themselves comparatively readily to oxidation.

On the other hand the extreme complexity of the acid-forming constituents, such as sulphur, oxygen, and nitrogen, and the limited knowledge of their reactional tendencies must also be taken into consideration in regard to this matter of oxidation. In other words, were these reactions known more positively or could turbine oils be so refined as to remove or neutralize their organic acid forming constituents, certainly the matter of water and the possibility of formation of permanent emulsions and sludges would be of far less importance.

As it is, effort can only be made in refinement to render turbine oils as chemically



Courtesy of General Electric Review

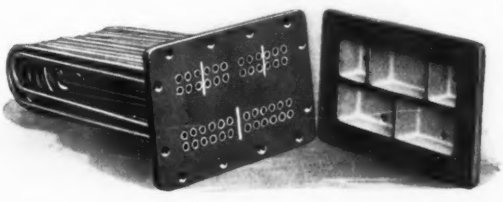
Fig. 7.—Chart showing change in friction with change in room temperature.

stable as possible. The most careful attention to the oil throughout the process of refining should always be observed. But no process renders an oil non-oxidizable when it is subjected to oxidizing conditions in the presence of heat and air.

*Maintaining Quality of Steam Turbine Oils in Service, "Power," January 22, 1924, by Charles H. Bromley.

Heat

The extent to which a turbine oil will be subjected to high temperatures will depend upon the turbine itself and the rate at which the oil is being circulated. During operation, therefore, the oil may either receive heat from an external source, such as the steam, or abnormal heat may be developed within the bearing, due to imperfections in the lubricating system causing unusual internal friction.



Courtesy of Moore Steam Turbine Corp.
Fig. 8.—An oil cooling device made up of a number of brass tubes as shown, which serves to keep the turbine oil at the proper temperature for most effective lubrication. This coil is customarily located in a water box in the bed-plate, being immersed in circulating cooling water.

Heat as received from the steam may be either conducted or radiated. At the high pressure end of the machine, conduction will be more probable, for steam at temperatures in the neighborhood of 600° Fahr. will certainly impart considerable of this heat to the adjacent bearings, regardless of the provisions for cooling these latter. Transmission of heat by radiation to the bearings as well as to the oil piping, will also occur to a certain extent, although this will naturally depend upon the provisions for ventilation, and the operating temperature of the turbine room.

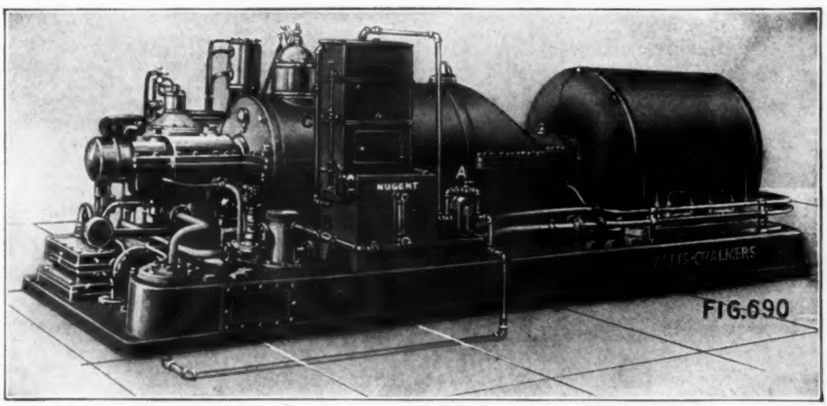
In connection with this matter of temperature, it is interesting to note that as a general rule room temperature variations which are oftentimes regarded as negligible factors, are in reality of considerable importance. As a rule, according to Gilson,* they will have a direct effect upon friction and the consequent temperature rise, these phenomena varying inversely with the room temperature.

*E. G. Gilson, "Some Bearing Investigations," "General Electric Review," May, 1924.

In Fig. 7 are shown the results of tests which he made on a standard type friction testing machine under three different room temperature conditions, varying from 16 to $24\frac{1}{2}$°C. (Approximately 61 to 76° F.). According to the load conditions, it is interesting to note the difference between the maximum and minimum temperatures obtained. These are so material, that under abnormally high conditions of room temperature they might easily be interpreted by an inexperienced operator as being indicative of impending bearing troubles; whereas, in all probability, the oil might be capable of giving perfect satisfaction.

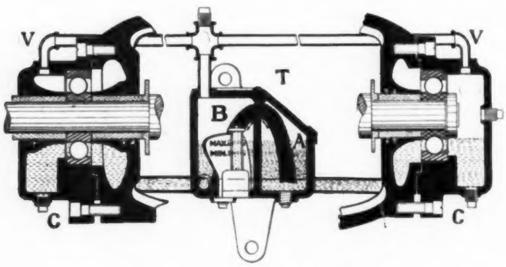
The generation of abnormal heat within a bearing may be the result of an excess of internal friction, due to the oil being too heavy or viscous, the circulation being too rapid, or perhaps the oil ways or ducts being partly clogged by emulsified matter. It is difficult to determine offhand just what the cause for overheating may be unless there is but little opportunity for the bearing to receive heat from external sources. In this event faulty lubrication can in general be assumed as being the cause.

Inasmuch as one of the chief functions of a turbine oil is to serve as a bearing coolant, it is perfectly evident that every precaution must be taken to keep the oil under circulation as cool as possible, otherwise its viscosity, and hence its pressure-supporting ability will be reduced, sometimes even to such an extent as to render the oil incapable of keeping the shaft from coming into actual metal-to-metal contact with the bearing. This is best attained by flooding the bearings with an excess of the right grade of oil under a certain definite pressure. While heat alone will lead but to the



Courtesy of Wm. W. Nugent & Co., Inc.
Fig. 9.—View of a steam turbine equipped with an oil filter for cleansing of the lubricating oil. The possibility for compactness of such an installation is evident. The piping and connections necessary are also clearly shown.

possibility of faulty lubrication from the viewpoint of lack of pressure-resisting ability, heat in company with water and air, is the forerunner of oxidation, emulsification, and the subsequent formation of insoluble sludges. Therefore every effort should be made to keep turbine bearing (and consequently oil) temperatures as low as possible. This is the primary reason for installing an oil cooler in connection with the lubricating system.



Courtesy of L. J. Wing Mfg. Company

Fig. 10.—Cross-section of the bearing housing of a turbine blower showing the method of lubrication "A" and "B" are two separate oil compartments connected solely by means of a set of wicks which replenish any oil that is used up out of "Compartment B." In this device the bearings themselves act as oil rings. At "V" are shown the vent pipes.

Oxidation

It has been brought out above that mineral oils will be subjected to more or less oxidation when agitated with water under higher temperatures in the presence of air. These conditions are normally so involved and so contingent upon one another that no one of them can be rightly claimed as being more detrimental than the other. The extent to which oxidation will occur depends largely upon the refinement of the original oil. In other words, as has already been mentioned, certain petroleum hydrocarbon fractions probably oxidize more readily than others. Logically, therefore, it would be advisable to bend every effort in their preparation to effect the removal of these compounds by more accurate refining. The more reliable the manufacturer, naturally the more dependence can be placed on his methods of refining.

Yet, regardless of this, oxidation will occur even with the best of oils, if they are subjected to oxidizing conditions. In fact wherever particles of air and water are suspended or retained within the body of an oil to form an emulsion, only a slight elevation of temperature during circulation or agitation will be necessary to bring about an oxidizing reaction between the air and oil. Oxidation furthermore is claimed to be aided by metallic particles, especially brass, copper and iron, or other foreign matter, such as dust and dirt. In fact in an already emulsified oil, foreign matter of this nature is regarded as being the co-partner of oxidation in producing the resultant insoluble sludges so detrimental to proper lubrication.

Now, according to certain authorities, if emulsion is prevented, sludging will be greatly lessened. But emulsion involves only air and water. It would therefore seem logical to consider foreign matter, or the catalyzers which promote oxidation, as an equal detriment. Emulsions alone are certainly not as viscous, adhesive and generally objectionable as insoluble sludges which so frequently clog oil passages, congest the oiling system and generally reduce the lubricating quality of the oil.

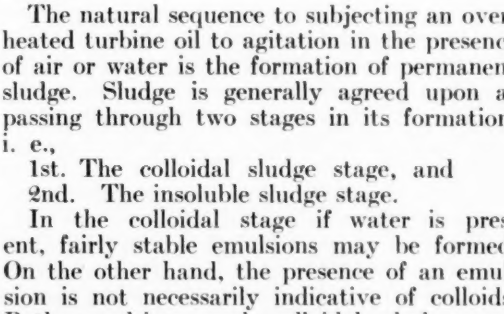
The natural procedure is therefore to reduce the effect by removing the cause as far as possible. In other words, by purifying the oil during operation, to a sufficient degree to keep down the percentage of water, emulsion and foreign matter. The latter can also be prevented to a considerable extent by using steel piping and fittings throughout the oiling system, for steel has the least tendency to chip, corrode or otherwise contaminate the oil with metallic particles.

Sludge

The natural sequence to subjecting an overheated turbine oil to agitation in the presence of air or water is the formation of permanent sludge. Sludge is generally agreed upon as passing through two stages in its formation, i. e.,

1st. The colloidal sludge stage, and
2nd. The insoluble sludge stage.

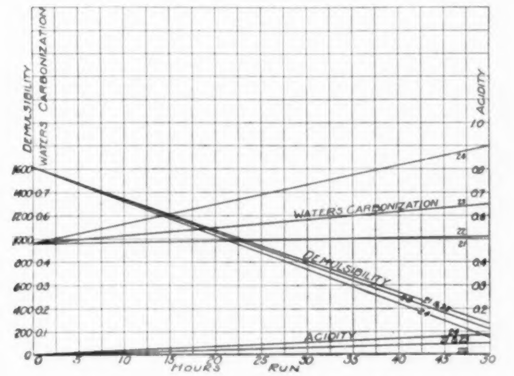
In the colloidal stage if water is present, fairly stable emulsions may be formed. On the other hand, the presence of an emulsion is not necessarily indicative of colloids. Both emulsions and colloidal sludges are relatively temporary at normal operating temperatures. Emulsions, if uncontaminated and unoxidized, will clarify themselves and precipitate water on standing, leaving the bulk of



Courtesy of National Electric Light Assn.

Fig. 11.—Relation of water to formation of sludge and emulsion. (See Fig. 3, Serial Report on Lubrication, Prime Movers Committee, 1923-1924.)

the oil in very nearly the same condition as prior to agitation. Colloidal sludges (or, as they may also be termed, soluble sludges), in turn, at temperatures above approximately 100° Fahr., will be held in suspension in oil. Yet while both emulsions and colloidal sludges can be apparently readily dissipated from, or absorbed by, the oil, they are nevertheless a



Courtesy of National Electric Light Assn.

Fig. 12.—Effect of air and water on acidity and oxidation of oil. (See Fig. 4, Serial Report on Lubrication, Prime Movers Committee, 1923-1924.)

detriment to lubrication while present, due to the fact that the formation of a continuous, uniform oil film over the surface to be lubricated is prevented.

Furthermore, in oils where breakdown has occurred, separation of contaminating foreign matter will be interfered with. As a consequence, this latter will be able to exercise its catalyzing effects to co-operate with oxidation in the bringing about of permanent sludges.

Of course, where colloidal sludges have passed over to the state of insolubility, immediate steps should be taken to correct this by the removal of the heavy, adhesive, relatively solid matter from the system, otherwise lubrication will be bound to be impaired.

In connection with this matter of sludge formation it is extremely interesting to again call attention to the experiments carried out by Mr. Gilson with experimental bearings run at high speeds, close clearances and therefore under relatively high temperature conditions. In his experiments he found that when his experimental bearing was run in an atmosphere of hydrogen, and oxidation was excluded, the internal friction was considerably higher than when air was admitted to the system. From this he concludes that oxygen is a necessary factor in maintaining the internal friction within the lubricant as low as possible. He furthermore believes that in all probability, it is the reaction of sludge formation and not this product itself which is of importance. In other words, it would seem that the act of lubrication is simply an act of oxidizing the oil.

On the other hand, while oxidation may be essential, to the attainment of satisfactory lubrication, the resultant product, i. e., the sludge is a detriment, just as has been stated heretofore. Due to its natural tendency when in an insoluble state, to accumulate in the oil pipes and oil ducts and not only impair the circulation of the oil, but also bring about an increase in internal friction, it is evident that this sludge should be removed. In its formation, according to Mr. Gilson, it is directly influenced by the temperature of operation. Therefore, this latter should be kept down as much as possible. Where the oiling system is free from congested matter, the oil itself will be enabled to carry out its partial function of serving as a bearing coolant most effectively.

It will be interesting to see how future work ties up with Mr. Gilson's theory, as exemplified by his experiments, and with those theories of boundry lubrication as brought out by other experimenters along these lines.

N. E. L. A. Tests

Certain very interesting tests run for the purpose of determining the effects of heat, water and air on a turbine oil are reported by the National Electric Light Association,* the apparatus used being a specially constructed sludge accelerator. Table I shows the respective conditions with the corresponding per cent. of acidity. To quote in further detail from this report:

TABLE I

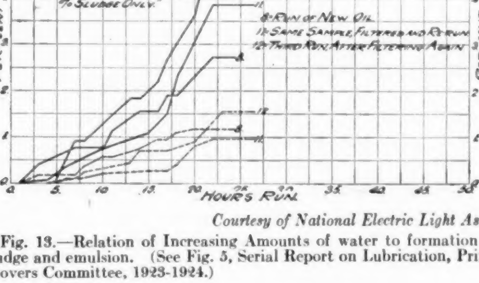
	No. of Run	*Per Cent. Acidity*
With Heat Alone	23	0.05
With Heat and Air	24	0.09
With Heat and Water	22	0.00
With Heat, Air and Water	21	0.05

"Attention is called to the fact that when water is absent, as in Runs 23 and 24, there is no formation of sludge or emulsion, but the acidity of the oil increases, as is shown in Table I and Fig. 12 of these runs. When water is present the amounts of sludge and emulsion both increase and seem to be approximately in proportion to the acidity that is formed when no water is present. In Run 21 which was made with heat, air and water, while sludge and emulsion were formed (Fig. 11), there was also some acidity present as

*Serial Report on Lubrication. Prime Movers Committee, National Electric Light Association. 1923-1924.

will be noted in Table I and Fig. 12, but this acidity dropped from 0.09, when no water was present, to 0.05."

"It is dangerous to draw conclusions from a single test but since the data presented have been confirmed by numer-



Courtesy of National Electric Light Assn.

Fig. 13.—Relation of Increasing Amounts of water to formation of sludge and emulsion. (See Fig. 5, Serial Report on Lubrication, Prime Movers Committee, 1923-1924.)

ous other different types of laboratory tests, it is felt that this test clearly points to what may be expected, and that if a large amount of water were present a still larger amount of emulsion would have been formed in Run 21, while the acidity would have been reduced still further."

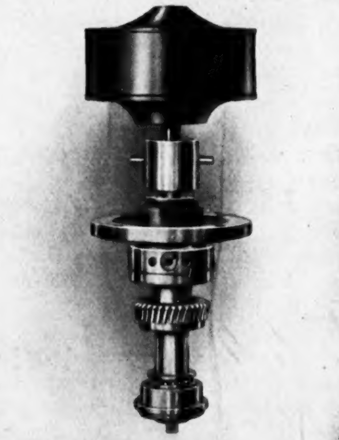
"Attention is called to the fact that while acidity was produced with heat alone, there is no doubt that some air was present in the oil and in the upper part of the machine which was responsible for the oxidation of the oil, thus forming organic acids."

"The tests that are shown in Fig. 13 confirm the statement made relative to the addition of a larger percentage of water. Run No. 8 was made on a given turbine oil. After the emulsification had reached a steady value the oil was filtered cold through a series filter which made it very brilliant. This oil was then re-run as shown on Run 11, since however, numerous samples had been taken during Run 8, it was necessary to maintain the volume of liquid in the accelerator by the addition of five per cent. of water, so that Run 11 was made with 15 per cent. of water. Likewise, after the same treatment Run 12, was made with 20 per cent. of water."

"It is to be noted that the amount of sludge and emulsion at the terminations of the runs increases with the increasing amounts of water. The amount of sludge, however, which depends upon the oxidation of the oil, not upon the water contained in it, has varied slightly and is not in proportion to the water present. This confirms the information shown in Fig. 11 and also indicates that the sludge and emulsion that are formed are due to the nature of the entire body of oil rather than to any particular ingredients that may be sludged out of the oil and leave the oil in better condition. This of course should be true of straight run oil, but where mixtures of various grades of oil have been made this condition will not hold."

REQUIREMENTS OF A TURBINE OIL

In view of the above, it is evident that there are certain definite requirements which a turbine oil must meet. It has been noted that the oil serves two primary purposes, one to lubricate or reduce friction to a minimum, the other to carry away heat. In order for an oil to lubricate it must be of the proper viscosity, for solid friction must be absolutely supplanted by fluid friction, this latter in turn being as low as possible. The viscosity or body of the oil is the controlling element, contingent, of course, upon the clearance spaces which exist between the shafts and bearings. As a general rule, the higher the clearances and the more accurately these are expanded by chamfering of the bearing edges at the point of entry of the oil, the more



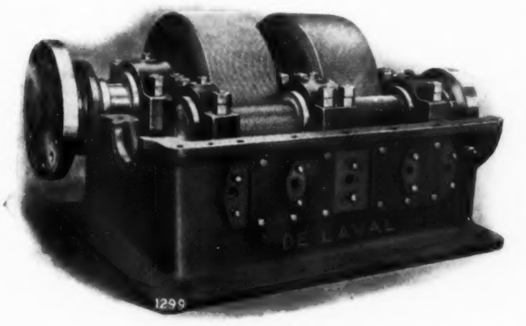
Courtesy of Moore Steam Turbine Corp.

Fig. 14.—A turbine oil relay governor. This is driven by a worm gear from the turbine shaft and actuates the oil relay pilot valve which admits oil pressure above or below an oil relay piston as necessary to control the movement of the steam regulating valve.

easily will the shaft be able to draw a suitable film of oil into this space. On the other hand, if the viscosity is too low the oil may not be

able to withstand the bearing pressures involved, or if it is too high there may be altogether too much internal friction brought about. Either of these conditions will lead to an appreciable increase in operating temperatures.

Therefore, in turn the oil must also be capable of acting as a cooling medium, for a certain amount of heat will be developed, regardless of how perfectly the operating conditions are adapted to effective lubrication. Cooling is effected by pumping a considerable excess of oil over that theoretically required for lubrication, through the bearing, in the assumption that such of the oil as does not serve to lubricate or support the rotating parts will carry away any excessive heat. Of course, if this is not brought about, the viscosity of the oil will in all probability be so reduced that the oil film will not be able to withstand the pressure of operation; in other words, it will break down and metal to metal contact will occur.

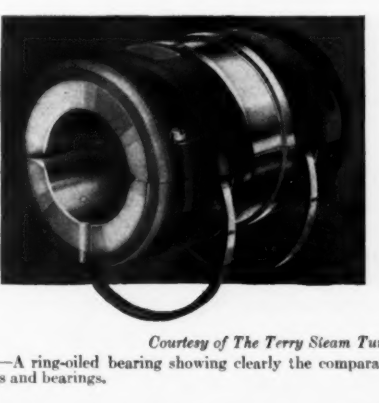


Courtesy of DeLaval Steam Turbine Co.
Fig. 15.—Gears and pinions of a modern reduction geared steam turbine, shown in place in the gear case with cover removed.

No definite data have as yet been derived which can be safely said to actually aid the operator in selecting oils of the proper viscosity. He is more or less up against a problem of "cut and try," according to the operating conditions involved. As a rule, however, he should have little difficulty inasmuch as turbine builders and oil refiners in company with the technical experts of a number of public utilities have co-operated to a sufficient extent to prove that an oil for turbine bearing lubrication should vary from 140-180 seconds Saybolt at 100 deg. F. although ring oiled bearings may require a somewhat heavier oil. Whether subsequent research will develop that for certain types of bearings and turbine construction, any more definite viscosities can be recommended is but a conjecture at this time.

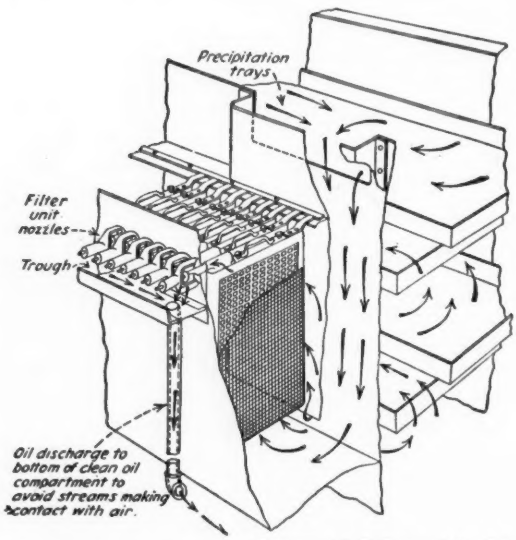
Where reduction gears are involved, whenever the same oil is to be used for lubrication of both gears and bearings, a certain increase in viscosity will be necessary in order to insure effective lubrication of the gears. Here duty will be considerably heavier, imposing pressures on the lubricating film in excess of those involved in the bearings. On the other hand this lubricant must not be so heavy as to lead to the development of abnormal internal friction within itself when in service in the bearings. An oil with a steep viscosity curve has been found to be the most adaptable for such service; that is, it should adhere to its original viscosity as nearly as possible when in service in the gear case; yet be capable of decreasing so rapidly in viscosity with normal increases in temperature, that when fed to the bearings at temperatures in the neighborhood of 140° F., it will be reduced to approximately the viscosity of the lighter oil which would normally be used for bearing lubrication alone. Wherever an oil is to be used for the lubrication of both reduction gears and bearings it should seldom have a viscosity below 300 seconds Saybolt at 100° F. In general, an oil of this viscosity will function with perfect satisfaction in the average stationary, reduction geared turbine. In marine service, on the other hand, the size of the gears may be considerably larger, with corresponding increases in tooth pressures. Therefore, it will often be found advisable, in such cases, to use an oil of approximately 500 seconds Saybolt viscosity at 100° F., or even higher in abnormal cases.

An important point to remember, however, in the lubrication of reduction geared turbines, is that we should never use an oil of any higher viscosity than absolutely necessary, due to the fact that the heavier the oil, the less readily will it separate from water. Furthermore, unless bearing temperatures are above the average, there will be a tendency for marked increase in internal friction, due to the oil being too heavy for the service involved.



Courtesy of The Terry Steam Turbine Co.
Fig. 16.—A ring-oiled bearing showing clearly the comparative size of the rings and bearings.

This, of course would lead to a certain increase in temperature, which would automatically tend to reduce the viscosity to a certain extent, with the result that ultimately an equilibrium temperature would be reached. We must,



Courtesy of S. F. Bowser & Co., Inc.

Fig. 17.—Details of a modern turbine oil filter which show the progress of the oil from the precipitation compartment through the filter units, to the clean oil compartment.

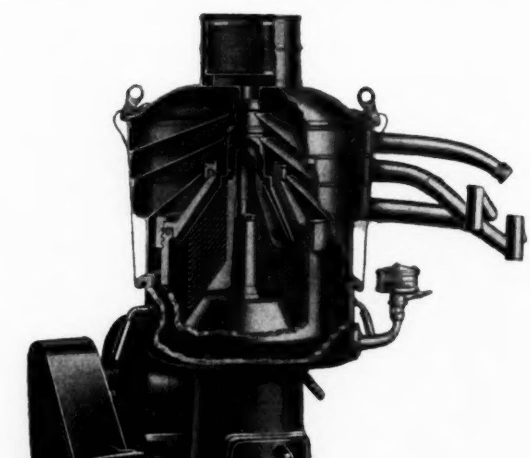
however, not overlook the fact that increase in temperatures will tend to increase the sludge formation.

Actually, therefore, the operator must watch his turbine temperatures carefully. If they tend to run above 140° F., unless there are certain mechanical conditions involved to which this can be directly attributed, he would be safe in investigating the suitability of his oil or the extent to which foreign matter and sludge are being removed.

RECONDITIONING OF TURBINE OILS

In order to insure that a turbine oil will continue to function effectively and meet the several detrimental conditions of operation discussed above, it must be maintained in a suitable state of purity. This does not necessarily mean that the oil requires reconditioning until its original characteristics are brought back. In general, operating and installation conditions will not permit of this. Experiments have proven that, unless the proportions of water, sludge and emulsified matter present are considerable, an oil will normally possess sufficient lubricating and cooling ability to function perfectly satisfactorily—in other words, bearing temperatures will remain below the generally accepted safe limit of 160° Fahr. Yet the oil in circulation at the time might contain a certain amount of the aforesaid recognized impurities, as well as considerable organic acidity.

Essentially, oil purification, filtration or reconditioning have one and the same meaning and involve the removal of foreign matter which in any way may tend to impair the lubricating or cooling ability of the oil. Oil reconditioning is, perhaps, the most generally understood term and will therefore be used hereafter where reference is necessary. In its attainment, it is based on one of three distinct principles, that is, the action of centrifugal force, the separation of the impurities from the oil by virtue of difference in specific gravity, or the removal of these impurities by means of some filtering medium. Each has its respective place, inasmuch as each is particularly capable of removing certain varieties of foreign matter. For example, where finely



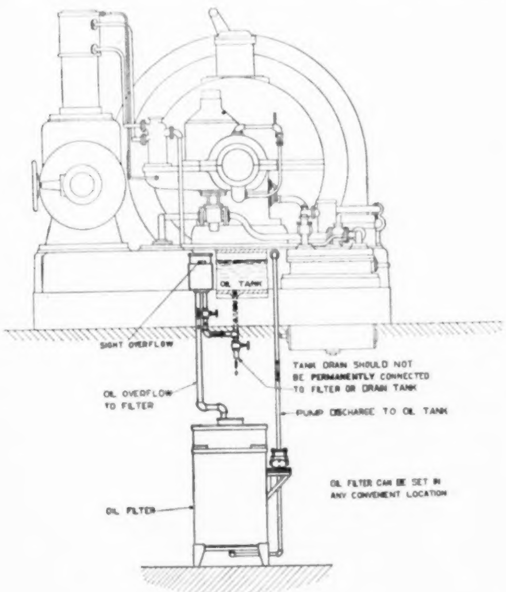
Courtesy of The DeLaval Separator Co.

Fig. 18.—Cross-section of an electric driven centrifugal purifier showing the arrangement of the bowl and the essential fittings attached.

divided carbonaceous matter is involved, which would be difficult to remove by precipitation, the addition of a certain amount of water and the subjection of the mixture to the violent action of centrifugal force, has been found to

bring about a sufficiently complete state of sludge formation to cause the impurities which are contained in this latter to be readily separated from the oil.

Precipitation and filtration are, in general, combined in the construction of the average apparatus which is to remove foreign matter



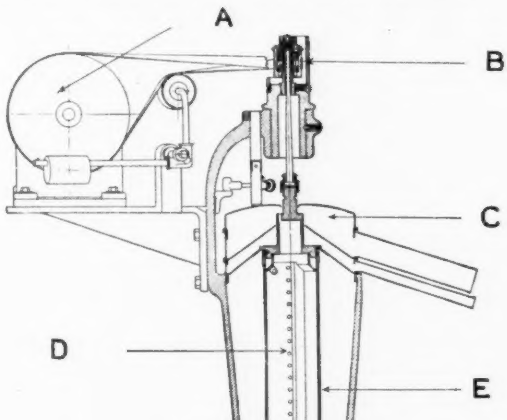
Courtesy of Allis-Chalmers Mfg. Co.

Fig. 19.—End view of a modern steam turbine equipped with an oil filter. Note location of this apparatus below the turbine and the necessary piping and fittings involved.

by either one of these methods. In devices of this sort, the oil is first subjected to precipitation, oftentimes the rate at which this latter occurs being increased by heating, or by chemical or mechanical means. To a great extent, precipitation depends on the length of time the oil is allowed to stand in a perfect state of quietude. It is natural to expect that were precipitation to be attempted in the presence of agitation or any movement of the medium, the efforts of the suspended impurities to settle out would be interfered with. In many cases, however, it will not be possible to give the time necessary for this; therefore precipitation becomes only a preliminary separation of such larger particles of foreign matter, as will settle out from the oil in a relatively short space of time.

Coming to filtration, it may be stated that it is advantageous, in that the time element is of relatively no importance. The efficiency which will be attained from filtration will, of course, depend upon the type of material through which the oil is to be filtered and the rate at which it is passed. As has been said above, it is not absolutely essential to remove every trace of impurity from the turbine oil. In fact, the oil in the lubricating system always contains a certain amount of foreign matter, with the exception of perhaps the first few minutes after new oil has been put into service. As a result, it is safe to say that the extent to which an oil must be cleansed or purified should be the governing factor as to the time of precipitation and the density of the filtering medium, or if both methods are used in combination, the relative effectiveness of each as compared with the volume of oil to be treated and the time available.

While water can often be effectively added to a turbine oil which is to be purified by means of centrifugal purification, it should not be understood that this also applies to the use of an oil filter. In other words, wet filtration, as it used to be known, or the idea of passing dirty oil through water, is now seldom used. The impurities are not removed to any extent and the oil particles will tend to



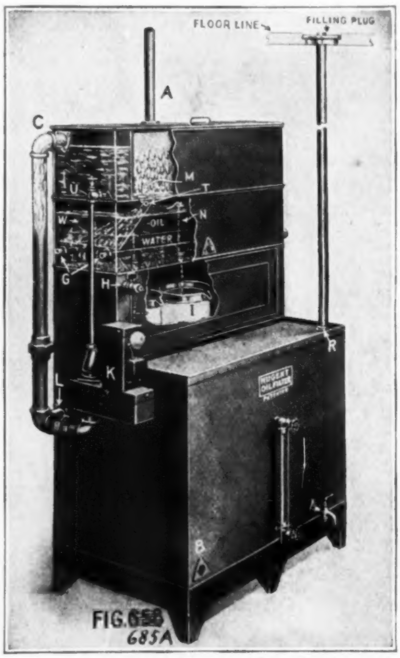
Courtesy of The Sharples Specialty Co.

Fig. 20.—Details of a centrifugal separator showing features of construction.

A is the motive power; B the bearing from which the bowl assembly is suspended; C the covers into which the liquids discharge after centrifugal treatment; D the wings to prevent slipping of liquid in bowl; E the bowl; F the cast iron frame; G the brake; H the guide bushing to prevent oscillation of bowl, and I the pipe carrying to the centrifuge substances to be treated.

absorb water, which will be difficult to remove later on. One of the most effective, though expensive, ways of bringing about the proper

reconditioning of turbine oils in the least possible time, is to use a centrifugal purifier in series with an oil filter. On the other hand, many concerns will not care to assume the additional expense entailed in the installation



Courtesy of Wm. W. Nugent & Co., Inc.

Fig. 21.—Details of an oil filter which combines both precipitation and filtration in the removal of water, sludge and solid foreign matter.

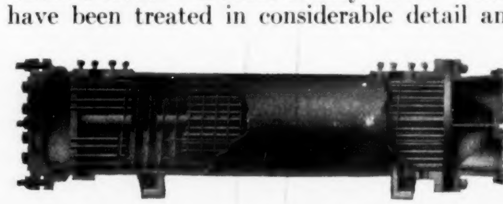
of both of these devices, hence they use whichever they may have available to the best of its ability.

Whatever means of reconditioning is to be adopted, it is well to give consideration to the matter of heating the oil. As a general rule, in order to facilitate the separation of impurities by reducing the viscosity of the oil, provision is usually made in the modern oil reclaimer, whatever its type, for the application of a certain amount of heat. For example, in connection with the operation of the centrifugal purifier with the average turbine oil, it will be found that heating to the neighborhood of 150° F. will oftentimes aid in the separation of the foreign matter. This, of course, will also depend to a certain extent upon the specific gravity of the medium involved. On the other hand, it must be borne in mind that the application of an excessive amount of heat will tend to bring about the formation of organic acids and additional oxidation. In other words, while it may facilitate the removal of some varieties of foreign matter to a certain extent, it will also lead to the subsequent formation of others, due to the purified oil coming back into service in an acidic state.

In regard to organic acidity, it is interesting to note that of the several impurities which will usually be found in a turbine oil, it is the only one which cannot be satisfactorily removed by any of the standard forms of oil reclaimers. As yet, however, the extent to which organic acidity is directly detrimental in itself, is a point of discussion. In the opinion of authorities, even though there may be no practical means of bringing about its removal from an oil, there is a possibility that addition of water to a turbine oil, prior to centrifugal purification, will by virtue of the emulsions and sludges formed, tend to automatically reduce the amount of organic acidity. As a result, the oil which is subsequently put into the system again will be capable of going that much further, before it is once more oxidized, and sufficient organic acidity developed to bring about a dangerous amount of emulsified matter and sludge. Of course, wherever water is to be added to a turbine oil, this should be done after the charge to be purified has been drawn off or by-passed from this system. Under no condition should this be done while the oil is in circulation, due to the fact that the excess of impurities which would probably be thrown down would form a sufficient amount of additional sludge to congest the system to a dangerous extent.

CONCLUSION

Within the limits of the space available we have attempted to discuss the matter of steam turbine lubrication from the all-important viewpoint of the operating conditions which a turbine oil must usually meet. These have been treated in considerable detail and



Courtesy of The Griscom-Russell Co.

Fig. 22.—A turbine lubricating oil cooler of the Multiwhirl type. In this cooler the oil is pumped through the shell, the cooling water being passed through the tubes.

we have drawn freely on the published data of recognized authorities for the purpose of emphasizing the accepted complexity of these conditions. With a clearer insight into the vast extent to which they affect steam turbine lubrication, it can be readily appreciated that the oil involved must be of the highest degree of refinement, for it is essentially the extent of refinement and not the source of the crude which should concern the consumer.

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